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Throwing History and Physical Attributes of Collegiate Baseball Pitchers and Their Association with Present Elbow Health

Kevin M. Walker

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This research is a product of the graduate program in [Kinesiology and Sports Studies](#) at Eastern Illinois University. [Find out more](#) about the program.

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Throwing History and Physical Attributes of Collegiate Baseball

Pitchers and their Association with Present Elbow Health

(TITLE)

BY

Kevin M. Walker

B.S., Eastern Illinois University at Charleston, 2003

THESIS

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Abstract

Throwing History and Physical Attributes of Collegiate Baseball Pitchers and their Association with Present Elbow Health

Kevin M. Walker

In the modern era of sports, major injuries occur as routinely as practice. There is no better example than in the world of baseball. The purpose of this study was to determine the factors that contribute significantly to elbow trauma in pitchers. Data was gathered from pitchers at the collegiate level of play. It was hypothesized that a pitcher's playing behavior in regard to pitch count, pitch type, and weekly pitching frequency would directly relate to a history of elbow injury. Also such factors as height, weight, pitching stride length, elbow joint laxity, upper and lower arm length, and flexion and extension of the elbow were examined to determine if they were significantly associated with injury. Twenty six collegiate baseball players were given a survey to seek information on their pitching history and current elbow health. All twenty-six surveys were completed and received for analysis. The questions on the survey included: how long they had been a pitcher, the types of pitches they threw, how long they have thrown those pitches, what their pitch counts were in the past and what it is at the present time. In addition, questions about their past and present elbow health were included. If the subject was injured they were asked to rate their pain on a scale of one to ten. The physical attributes measured were height, weight, joint laxity, stride length, elbow flexion and extension, and upper, lower and total limb length. The survey was completed during the collegiate season. After all the data was collected, the subjects were placed into three groups, an injured group, a pain group, and a no injury/pain

group. Descriptive statistics were calculated for the dependant variables by group. Differences among the groups for dependent variables were assessed using ANOVA (SPSS version 11.5). An alpha level of less than .05 was used to indicate statistical significance in this study.

There was no evidence that pitch type or pitch count was associated with elbow injury. Pitching frequency at the little league and high school levels were higher in groups that experience pain and injury. There was less range of motion in elbow flexion in the group that had injury than in the group with pain only. Subjects in the injured group had a longer upper limb than the pain group. No other physical measurement was associated with risk of injury in the elbow in this limited sample of baseball pitchers.

It was concluded from these results that a high pitching volume (frequency * pitch count) at a young age, limited range of motion in elbow flexion, and longer limb length may contribute to a higher risk of elbow injury by the time pitchers reach the college level.

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I would also like to thank the following people for helping me gather my data; EIU head baseball coach Jim Schmitz, Lakeland College head coach Jim Jarrett, Bo Leonard and Ryan Newby, all the baseball pitchers that I used as subjects, and Steve Jackson for helping out with some editing.

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And to all the people (guys and girls) of 719 Lincoln, have a great year and good luck....ALL DAY!

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CHAPTER I

INTRODUCTION

In the modern era of sports, major injuries come as routinely as practice. There is no better example than in the world of baseball. A countless number of pitchers have had their careers cut short or have never been able to pitch to their full potential because of elbow injury. Examining a pitcher's throwing history may aid in predicting their present elbow health. Several of the factors that may be important to elbow health include: at what age they first learned to pitch a curve ball or slider and when they started to regularly use that pitch, if they had a pitch count when they first started in little league and if a pitch count has been maintained throughout their career; finally, whether the pitcher ever participated in any type of regular exercises that may help prevent injury. It is commonly believed that the more a pitcher over uses his arm at an early age the more prone they are to injury. The more a pitcher controls his pitching, both on and off the field, the less likely an injury will occur (Cain et al. 2001).

Perhaps no throwing motion is more dynamic than baseball pitching. As a result there is a high probability for elbow injuries in baseball pitchers (Werner et al., 1993). In pitchers, ulnar collateral ligament injury is one of the most common causes of elbow pain and swelling during and after motions of pitching a baseball (Singh et al., 2001). Injury sustained to this joint can ultimately lead to the rupture of the ulnar collateral ligament. A UCL rupture is considered to be one of the worst injuries for a pitcher to overcome (McNeal, 2002). Hundreds of amateur and professional baseball players have had UCL surgery done. A recent report showed there are 75 active major leaguers who have had

surgery to repair their UCL (McNeal, 2002). Over a six year period Dr. James Andrews performed 91 UCL reconstructions, Thirty-seven (41%) were professionals, 41 (45%) were collegiate, and 7 (7.7%) were high school or recreational baseball pitchers (Azar et al., 2000).

A study conducted by Lyman, Fleisig, Andrews, and Osinski (2002) concluded that pitchers of a young age group should be cautioned against throwing curveballs and sliders, limit their innings pitched, and pay attention to biomechanics of the overhead throwing motion to help decrease the risk of elbow and shoulder pain (Lyman et al., 2002). Along with the factors mentioned in the previous study, physical measurements such as stride length, limb length, height, weight, elbow flexion, elbow extension, and joint laxity should be taken into consideration for injury. Some of these factors can increase or decrease the risk of injury.

Purpose of the Study

The purpose of this study was to determine whether pitching history and certain physical attributes were significantly associated with elbow trauma in collegiate baseball pitchers.

Hypothesis

It was hypothesized that a pitchers playing behavior in regard to pitch count, pitch type, and how often they pitched during a week would directly affect their present elbow health. It was further hypothesized that factors as height, weight, pitching stride length, elbow joint laxity, upper and lower arm length, and flexibility and extension of the elbow were examined to determine if they contribute to the likelihood of injury.

Definition of Terms

The following terms will be used in the present study as defined below:

Articulate – A joint; formation of words (Martini & Timmons, 1997)

Isometric contraction – A muscular contraction characterized by rising tension production but no change in length (Martini & Timmons, 1997)

Isotonic contraction – A muscular contraction during which tension climbs and then remains stable as the muscle shortens (Martini & Timmons, 1997)

Kinematic – Describing a motion (Reinhold, et al. 1995)

Kinetic – What causes a motion, i.e., joint forces and torque (Reinhold, et al. 1995)

Pronation – Rotation of the forearm that makes the palm face posteriorly (Martini & Timmons, 1997)

Supination – Rotation of the forearm so that the palm faces anteriorly (Martini & Timmons, 1997)

Torque – The measure of a forces tendency to produce torsion & rotation about an axis (Arnheim and Prentice, 2000)

Valgus – Position of the body that is bent outward (Arnheim and Prentice, 2000)

Varus – Position of the body that is bent inward (Arnheim and Prentice, 2000)

Limitations of the Study

The subjects in this study were not randomly selected, and were from a relatively small geographic area, therefore, the findings of this research may not be applicable to all baseball pitchers from various levels of competition, or region of the country. Also the

subjects that were chosen for this research all represented the same age group and similar ability level.

Significance of Study

The present study will investigate both a pitchers history and physical measurements. Most studies evaluated only the history and one or two physical measurements, or just physical measurements and one or two questions concerning history. It is important to examine both history and physical attributes in the same group of subjects because it will take into account more factors that can help better predict a elbow injury in a baseball pitcher.

CHAPTER II

REVIEW OF RELATED LITERATURE

The elbow is one of the most frequently injured joint in the world of baseball pitching. The ulnar collateral ligament is the primary ligament providing the elbow with the stability it needs to perform its most basic functions and is the most commonly sprained ligaments in pitchers. A pitcher's past will directly affect his likelihood for future injury. The purpose of this study was to determine which factors are most related to serious elbow trauma in collegiate pitchers. The anatomy of the elbow, the biomechanics of the overhead throwing motion, injury mechanisms, surrounding musculature, and the rehabilitation and prevention are several areas that are involved in better understanding elbow injury in collegiate pitchers.

Anatomy of the Elbow

To understand how an injury to the elbow occurs it is important to understand the anatomy of the elbow. The elbow is a hinge joint, one that permits angular movement in a single plane, similar to the opening and closing of a door. There are three bones that articulate at the elbow joint, the ulna, radius, and the humerus. The trochlea of the humerus articulates with the trochlear notch of the ulna and the capitulum of the humerus articulates with the head of the radius (Martini and Timmons, 1997).

There are several ligaments in the elbow joint. The major ligaments are the ulnar collateral ligament (UCL), radial collateral ligament (RCL), and annular ligament (AL) (Arnheim and Prentice, 2000). The ulnar collateral ligament or medial collateral ligament is on the medial side of the joint connecting the ulna and humerus. It is comprised of a

strong anterior band with weaker transverse and middle sheets of tissue (Gray, 1977).

The ulnar collateral ligament is the ligament that if injured, can result in the need for

UCL repair which is commonly known as Tommy John surgery (McNeal, 2002). The

radial collateral ligament is on the lateral side of the elbow and connects the radius and

the humerus. The last major ligament of the elbow is the annular ligament, which attaches

to the anterior and posterior margins of the radial notch and goes around both the head

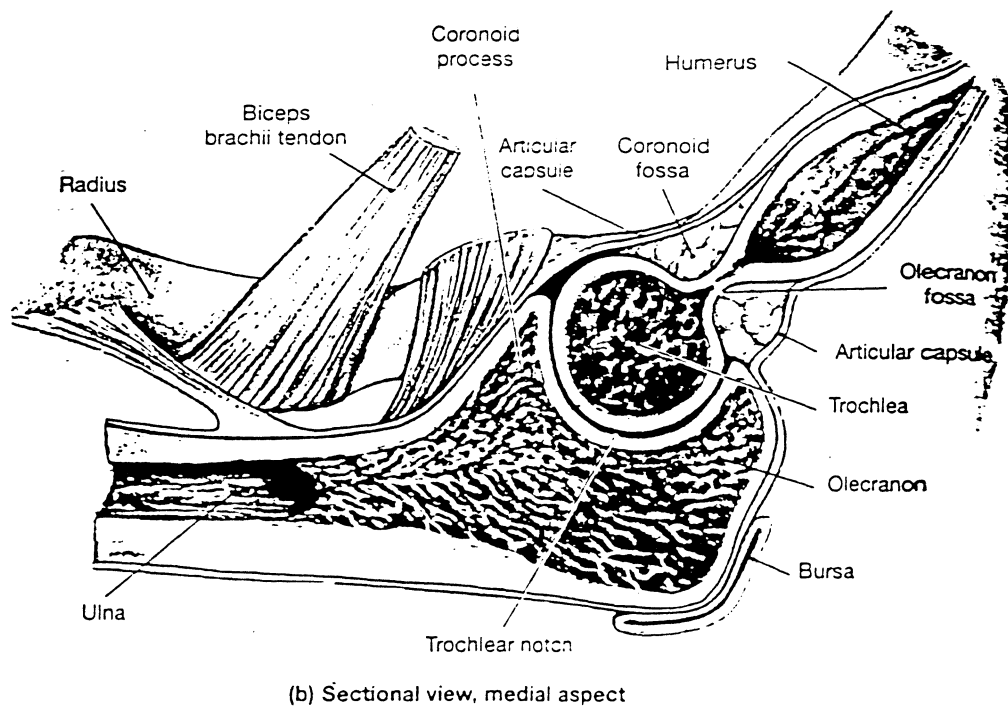
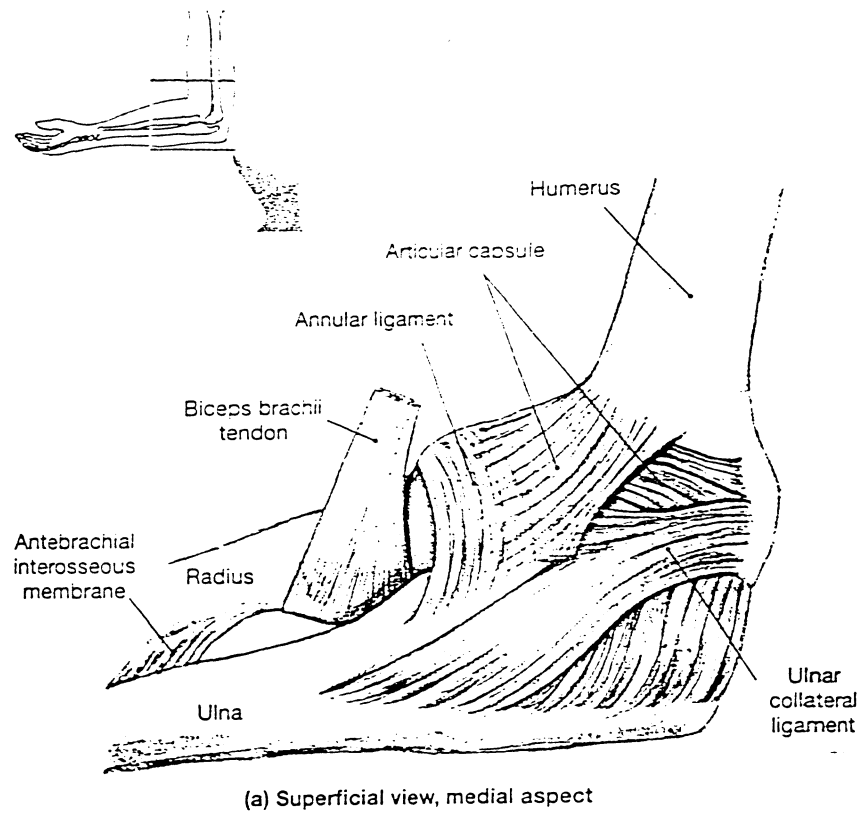
and the neck of the radius (Arnheim and Prentice, 2000). (Figure 1)

The synovial membrane of the elbow is very broad. It was described by Martini and Timmons 1997, as an incomplete layer of fibroblasts confronting the synovial cavity plus the underlying loose connective tissue (Martini and Timmons, 1997). It covers the edge of the articulating surface of the humerus and lines the coronoid and olecranon fossa on the humerus. The synovial membrane covers the anterior, posterior and lateral ligaments of the elbow. There are also folds that project into the synovial cavity between the ulna and radius (Gray, 1977).

There are three masses of fat in the elbow joint. These masses are in between the capsular ligament and the synovial membrane. The largest fat mass is above the olecranon fossa, and is pressed into the fossa by the triceps during elbow flexion. The second mass is over the coronoid fossa. The third and final mass is over the radial fossa. The second and third masses are pressed into there respective fossa during extension of the elbow (Gray, 1997).

There are several muscles that are associated with the elbow joint, though some are more important to the biomechanics of pitching. The muscles in the elbow complex can be divided into four groups. The first muscle group associated with elbow

Figure 1 Ligaments of the Elbow (Martini & Timmons, 1997).



movements are the flexors. The three muscles in this group are the biceps brachii, brachialis, and the brachioradialis (Martini and Timmons, 1997). The biceps brachii originates on the coracoid process and supraglenoid tubercle of the humerus, and inserts into the tuberosity of the radius. The brachialis is originated on the anterior, distal surface of the humerus and runs distally to attach itself on the tuberosity of the ulna. The brachioradialis's origin is the lateral epicondyle of the humerus, from where it runs down to the lateral margin of the olecranon process of the ulna (Martini and Timmons, 1997).

The next group of muscles of the elbow joint are the extensors. There are only two muscles involved in this movement, the triceps brachii, and the anconeus. The triceps brachii has three heads; a long head, a lateral head, and a medial head. The long head originates on the infraglenoid tubercle of the scapula, the lateral head originates on the superior, lateral margin of the humerus, and the medial head originates on the posterior surface of the humerus inferior to the radial groove. All three heads of the triceps brachii insert at the olecranon process of the ulna. The anconeus is a smaller muscle that extends the elbow, and aids in moving the ulna laterally during pronation (Martini and Timmons, 1997).

The final two groups of muscles are the pronators and the supinators. The biceps brachii is one muscle that performs the action of elbow flexion and supination of the forearm. The supination of the forearm is an important movement in throwing various types of pitches. The brachialis and the brachioradialis also perform flexion. The brachioradialis also will pronate if the forearm is supinated and supinate if the forearm is pronated. There are two muscles that perform pronation, the pronator quadratus and the pronator teres. The pronator quadratus originates on the medial surface of the distal

portion of the ulna and inserts on the anterolateral surface of the distal portion of the radius (Martini and Timmons, 1997). The pronator teres muscle originates on the medial epicondyle of the humerus and the coronoid process of the ulna and it inserts on the distal lateral surface of the radius (Martini and Timmons, 1997).

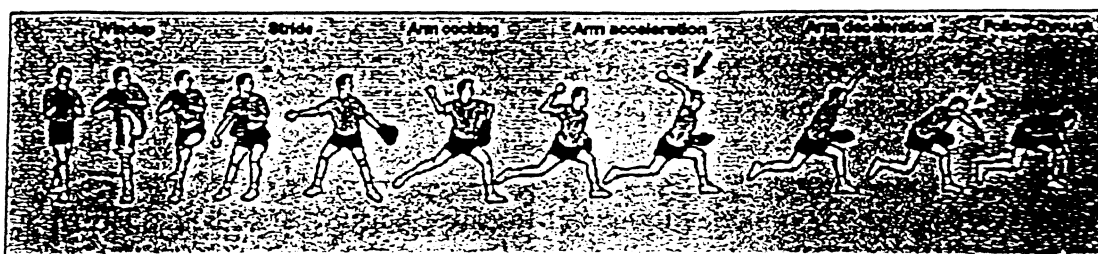
Biomechanics of the Overhead Throwing Motion

The most common way a pitch is thrown is by using the overhead throwing motion. This requires several movements of the shoulder, elbow and wrist. The overhead throwing motion in baseball pitchers can be divided into six stages, the wind-up, stride, arm cocking, arm acceleration, arm deceleration, and follow through (Whiteside et al. 1999). (Figure 2) During these six phases several muscles of the shoulder, elbow and wrist are being utilized.

Proper throwing mechanics begin with the wind up stage. The wind up stage allows a pitcher to assume a good starting position, which will in turn generate momentum to help accelerate the ball. A proper windup creates less activity in the elbow, decreasing stress on the elbow (Reinhold et al., 2000). During the windup phase it is important to maintain good balance, keep the shoulders steady, and lift the leg, flexing from the hip. Also, the pitcher should stand tall and keep his body weight back (Congeni, 1994).

The stride phase of the overhead throwing motion allows the athlete to extend forward. Within this phase, the elbow might reach up to 85 degrees of flexion by the time the foot has made contact with the ground (Fleisig, Andrews, et al. 1995). It is important to keep the leg stride slightly less than a pitchers height (Congeni, 1994). The stride

Figure 2 Phases of the Overhead Throwing Motion (Whiteside et al. 1999)



phase is important in maintaining balance (Corral & Weinstein, 2002). As the stride leg is lifted the weight is placed on the pivot foot. Once the knee reaches waist high it will start its descent. The foot should plant at the heel first, this is where the weight will begin to transfer to the stride leg (Corral & Weinstein, 2002).

During the cocking and acceleration phases the hands begin to separate with the throwing hand remaining up high. There should also be an appropriate amount of body rotation so not as much stress is placed on the arm (Congeni, 1994). The arm cocking phase begins with front foot contact and ends when the shoulder reaches its maximum external rotation (Rizio, 2001). This phase is also where there is the maximum amount of external rotation of the arm. This requires a varus torque to offset the valgus extension of the elbow. The joint is stabilized during these high levels of torque by the UCL, with help from a small number of muscles in the surrounding area (Reinhold et al., 2000).

During the acceleration phase the elbow extends, the arm swings down, and the ball is released (Reinhold et al., 2000). The acceleration phase lasts from maximum external rotation until the release of the baseball. During this phase the humerus abducts, horizontally adducts, and internally rotates at velocities approaching eight thousand degrees per second (Arnheim and Prentice, 2000).

During the arm deceleration phase and the landing phase the pitcher should land with the toes pointed towards the batter and balance should be maintained. At the beginning of the landing phase, the elbow should be at an even height with the shoulder. The landing phase is right before the ball is released. The follow through is equally important in maintaining good elbow health. Again, sustaining good balance is the key in this phase. Also, the pitcher should be sure the back shoulder moves toward the batter

and becomes visible from home plate, and that the chest should almost be horizontal to the ground (Congeni, 1994).

All of these components should be done correctly to maintain elbow health. This motion should be a smooth fluid one. Anyone of these phases done wrong can result in a elbow or shoulder injury (Congeni, 1994).

Injury Mechanisms of the Pitching Elbow

Most pitching injuries of the elbow are considered acute injuries, though, some injuries may be caused by years of elbow abuse and can be considered overuse injuries. Today, with more athletes starting to compete at an early age, longer playing seasons, and increased conditioning programs, most sports do not allow for adequate healing time. These combined factors may result in an increased risk for overuse injuries (Stanitski, 1993). These injuries are the result of repetitive micro traumas to a given area, and can lead to inflammation and/or local tissue damage over a period of time (O'Connor, et al., 1997). Unlike other overhead throwing motions, pitching puts severe valgus stress across the medial joint line of the elbow. The anterior bundle of the ulnar collateral ligament is the principal restraint to valgus force placed on the elbow from 30 degree to 120 degrees of flexion and is the primary stabilizer (Cain et al. 2003).

Typically it is in the cocking and the early arm acceleration phase that the UCL can tear (Glousman & Barron, 1992). In athletes with UCL instability, nearly 85% will experience pain during the arm acceleration phase of throwing, whereas less than 25% will experience any type of pain during the deceleration phase (Cain et al. 2003).

Kinematic data of pitchers has shown that at the instance of the arm cocking phase the

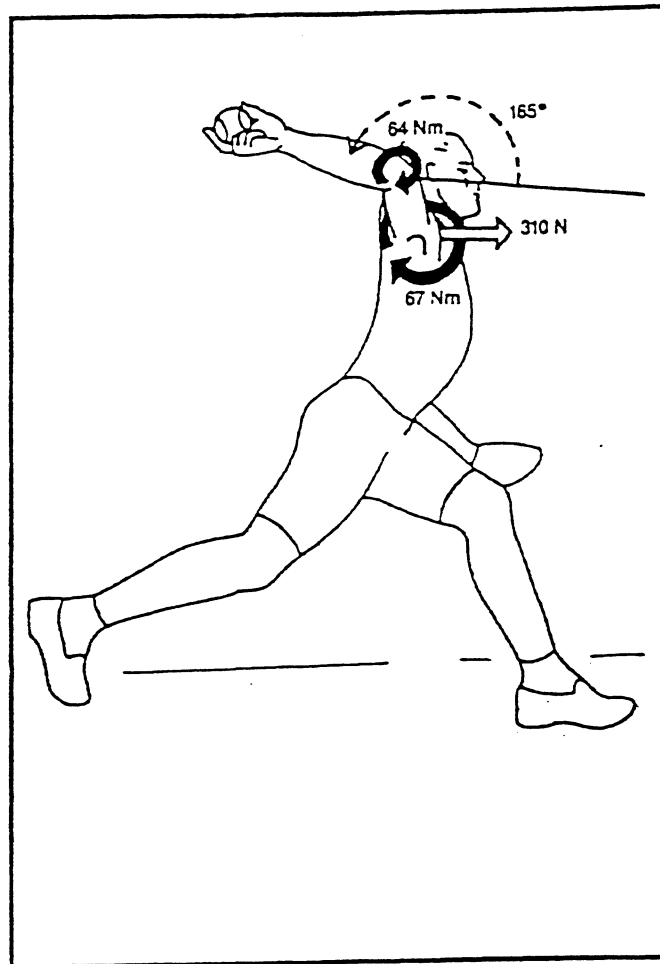
arm is in approximately 165 degrees of external rotation, 94 degrees of horizontal abduction, and 95 degrees of elbow flexion (Fleisig, Andrews, et al. 1995). The kinetic data shows at the instance of arm cocking 64 Nm of varus torque, 16 Nm of flexion torque, 300 N of medial force, 160 N of anterior force, and 270 N of proximal force (Fleisig, Andrews, et al. 1995). (Figure 3) The force placed on the elbow during pitching produces a great deal of stress on the stabilizing structures, especially the UCL (Reinhold, et al., 2000).

Fleisig, Andrews, Dillman, and Escamilla (1995) conducted an examination of the mechanisms of overuse injuries by looking at kinetic data. The examination involved twenty-six healthy adult male pitchers, highly skilled, with an average age of 22 years. Each subject was screened on their background to assure they were completely healthy, and each subject had their height, weight, and lengths of the radius and humerus recorded before testing began (Fleisig, et al. 1995).

The testing began with each subject performing a normal warm-up. Reflective markers were then placed on anatomical landmarks of both the upper and lower extremities. Four high-speed, charge-coupled device cameras were used to record the location of the reflectors during the motion of pitching. After the reflectors were in place the subjects threw ten fastballs, and of the ten pitchers, the data of fastest three were taken (Fleisig, Andrews, et al. 1995).

The kinetic information was used to determine where maximum torque took place during the pitching motion. The authors concluded that the maximum elbow varus torque, produced at the time of maximum shoulder internal rotation torque, was identified as the primary load related to injuries to the elbow. They also identified two critical points in

Figure 3 Stress Placed on the Elbow at the End of the Acceleration Phase (Reinhold et al., 2000).



shoulder overuse injuries. Those two points were recognized as the point of maximum internal rotation torque during the arm cocking phase and the instant of maximum compression force during arm deceleration (Fleisig, Andrews, et al. 1995).

This study examined the biomechanics and used kinetic information to determine how injuries might occur. The study increased the amount of factual evidence involving peak elbow torque and its relationship with overuse injuries; unfortunately, these athletes did not have any elbow injuries. The only factor that may have hindered this study is that the pitchers had no elbow pain. Therefore, other factors can be looked at besides where peak elbow torque is. Further research should examine pitchers with poor mechanics and pain during pitching. This could demonstrate the difference in elbow valgus torque in healthy and non-healthy pitchers. The author also adds that valgus torque applied to the elbow by the forearm has to be countered with a varus torque to the forearm by the elbow for a decrease in injury (Fleisig, Andrews, et al. 1995).

Elbow injuries may begin to take form at an early age. A substantial overuse injury observed in younger athletes is called little league elbow. In immature athletes, repeated stress on the elbow can cause the unfused medial apophysis to tear away from the epicondyle of the humerus. In this case, the ulnar collateral ligament may remain undamaged, but it is rendered incapable of providing medial support (Whiteside et al. 1999). Early recognition of this injury can help prevent later UCL injury in the more mature athlete. Also instructing young athletes proper throwing mechanics would help to greatly reduce its chance of developing this injury (Klinge & Kocher, 2002).

Lyman, Fleisig, Waterbor, Funkhouser, Pulley, Andrews, Osinski, and Roseman (2001) examined the relationship between pitch type, pitch volume, and other risk factors that may contribute to elbow injury in youth baseball players.

The authors examined 298 youth pitchers over the span of two baseball seasons. The mean age of the pitchers was 10.8 years. In addition to the fastball most of the pitchers threw a changeup and about one third threw a curveball. The sinker, slider and knuckleball pitches were also reported as being thrown. Each participant was contacted after each game over the telephone and was asked a variety of questions (Lyman et al., 2001).

They were asked to rate their pitching performance, how many innings they pitched, how many pitches they threw, and if they were experiencing any type of pain in their shoulder or elbow. The pitchers totaled 2699 appearances, which meant a per player average of nine games a season, with 2.4 innings pitched per outing. Each subject threw a mean of 43 pitches per outing. The subjects also classified their performance as either good or excellent 70 percent of the time. The most common complaint was shoulder pain, which was reported by 32 percent of pitchers in seven percent of pitching outings. There was also elbow pain reported in 25 percent of pitchers in 4.5 percent of pitching outings (Lyman et al., 2001).

Total pitches and pitch type factored into elbow pain. There was a 6 percent increase in pain per every ten pitches, and after 75 pitches, odds of elbow pain increased over 50 percent. The use of the split finger fastball, forkball, and sinker resulted in an increase of elbow pain as well (Lyman et al., 2001).

This study also looked into such factors as age, height, weight, and cumulative pitches thrown. Stride length was also examined as apart of the pitching mechanics portion of the testing. The stride was examined through a video recording of the pitchers. However, stride length did not correlate with an increase risk in injury in this study (Lyman et al., 2001). Cumulative pitches thrown referred to the number of pitches thrown before the game, during the game, in between innings, and after the game. The study showed that a cumulative pitch count between 300 and 599 decreased the risk of elbow injuries while a cumulative pitch count of over 600 increased the risk of pain and injury. Increased age, increased weight, and lower height were all considered significant independent risk factors for elbow pain. The authors hypothesized that heavier pitchers may be putting a greater burden on their elbow thus increasing injury risk (Lyman et al., 2001).

In a similar study examining little league pitching problems, Lyman, Fleisig, Andrews, and Osinski (2002) performed a study looking at several different pitching habits. The authors looked at the pitch count, pitch type, pitching mechanics, and shoulder and elbow pain of the subjects. This study had a total of 476 young baseball players ranging in age from nine to fourteen years. The subjects were followed for one season. The data collected included pre and post-season questionnaires, pitch count logs, video analysis, and injury and performance interviews after each game. The study found that half of the subjects experienced elbow or shoulder pain during the season (Lyman et al. 2002).

The curveball was associated with a 52 percent increase in pain in the shoulder. In the elbow, the slider was associated with an 82 percent increase in pain. The results of

this study suggests that breaking pitches contribute to more elbow and shoulder pain and should be thrown at an older age. There was also a positive correlation between shoulder or elbow pain and the number of pitches thrown (Lyman et al. 2002).

The authors of both these studies used a large group of little league pitchers as subjects. However, there were limitations to their studies. In the first study the interviews were conducted over the phone an hour after the subjects pitched. This could effect the outcome of the study. That is because the subjects had time to heal after pitching. So if they had gotten some soreness after the game they could already been feeling better. Also, interviewing over the phone could have given the subjects less understanding of the survey, thus some of their answers could have changed had they been interviewed in person. If they were interviewed in person they could have taken more time with asking questions and understanding more about the survey. It's true that it would have been difficult to interview all the subjects immediately following a game, so the researchers may have wanted to decrease the number of children who participated in the study.

Another type of injury that can occur due to heavy stress placed on the elbow during valgus extension is valgus extension overload. This happens when an elbow is exposed to repetitive valgus stress, which can lead to several problems in the elbow including medial traction, lateral compression, and intra-articular impingement. All of these can lead to injuries to the UCL, medial epicondyle apophysis, lateral compartment, and posterior olecranon (Fox, Jebson, & Orwin, 1995).

Another study looked solely on pitch count. The study was developed by Donald Marshall ATC and Dr. Joseph Congeni (1994). The subjects in the study were eight to ten year old boys from the Akron, Ohio area in three separate little leagues. The observers

examined 100 innings and counted the number of pitches thrown without regard to what pitch was thrown. The mean number of pitches thrown per inning was 33.5, with a range of eleven to 56 pitches. The study concluded that many of the young pitchers threw over 100 pitches a game (Congeni, 1994). The author concludes that any help aimed at preventing little league elbow must address pitch count, regardless of pitch type (Congeni, 1994).

The study by Congeni and Marshall looked only at pitch count, but did not relate it to injury. The survey just looked at how much a little league pitcher was pitching. Injury status should have been considered in the study.

A number of ulnar collateral ligament problems can be easily detected. UCL sprains are very common in throwing activities, and are characterized by pain on the medial joint line that becomes worse with activity. The pain generally subsides with rest but returns on continuation of throwing at over 70 percent of normal velocity (Chumbley, O'Connor, & Nirschl, 2000).

Joint Laxity and Its Role in UCL Injury

There have been several studies that examine the role of medial joint laxity in the elbow and its affect on baseball pitchers, one such study was done by Ellenbecker, Mattalino, Elam, and Caplinger (1998). The purpose of this study was to determine whether or not there was a difference in laxity in the dominant and non-dominant arms of forty uninjured baseball pitchers. The forty subjects were pitched on the professional level and were tested bilaterally with a Telos GA-IIIE stress radiography device. Joint space width was measured between the trochlea of the humerus and the coronoid process of the ulna (Ellenbecker, Mattalino, Elam, & Caplinger, 1998).

The mean age of the subjects was 21.7 years, their height was 73.3 inches, their weight was 202.5 pounds, their mean starting pitching age was ten years, while the mean years in which they have been a professional pitcher was 2.76 years (Ellenbecker et al., 1998). Active range of motion was also measured in the study using a standard goniometer. After flexion and extension was recorded the subjects began the valgus stress testing (Ellenbecker et al., 1998).

There were differences found in laxity in the dominant and non-dominant arms. The dominant elbows with stress opened on average 1.20 ± 0.97 mm, while the nondominant elbows opened 0.88 ± 0.55 mm (Ellenbecker et al., 1998). There was also differences in flexion and extension between arms. The dominant arms had five degrees less extension. There were no mention of any significant difference in elbow flexion (Ellenbecker et al., 1998).

The study confirmed that there were differences in elbow laxity in dominant and non-dominant arms in baseball pitchers. There is still more to be done. For instance a study comparing injured dominant arms and non-injured dominant arms. The study did show the difference in extension and flexion in healthy pitchers, further research could be done with injured pitchers.

A study by De Smet, Winter, Best, and Bernhardt (2002). This study observed two subjects who had sustained elbow injuries. The first subject was a twenty one year old college pitcher who had injured his dominant arm five months earlier while lifting concrete (De Smet, Winter, Best, & Bernhardt, 2002). He eventually started pitching two and a half months after the initial injury and reported no initial elbow pain. However, he did start feeling elbow pain while pitching shortly after there. The pain was along the

medial epicondyle during valgus stress (De Smet et al., 2002). Both elbows were examined using sonography with valgus stress and without. The examination discovered an abnormal hypoechoic area in the proximal UCL in the injured elbow (Ellenbecker et al., 1998). The joint in the injured arm showed a laxity of 2.7 mm when relaxed and 4.6 mm when valgus stress was applied. In comparison the uninjured elbow measured at 1.9mm when relaxed and 2.1mm under valgus stress (De Smet et al., 2002).

The second case was a seventeen year old high school pitcher who six months prior to examination felt a sharp pop in his throwing elbow. The pain persisted along the medial aspect of the elbow. He was able to play hockey without any pain, but he could not pitch. Physical examination revealed a full range of motion with tenderness at the medial epicondyle (De Smet et al., 2002). Like the first case, sonography was performed on both elbows. The injured elbow showed 2.3mm of laxity when relaxed and 5.6mm of laxity when valgus stress was applied. The healthy elbow revealed 1.2mm when relaxed and 1.5mm under valgus stress (De Smet et al., 2002).

This study illustrates that valgus stress maybe a good indicator of UCL injury. The study may have benefited by using more subjects.

Pomianowski, O'Driscoll, Neale, Park, Morrey, and An (2001) examined the effect of forearm rotation on medial elbow joint laxity. The purpose of the study was to determine whether or not forearm rotation influenced laxity during valgus or varus stress to the elbow (Pomianowski, O'Driscoll, Neale, Park, Morrey, & An, 2001).

The subjects were nine fresh-frozen upper extremities from cadavers. Six of the specimens were from the right side and three were from the left. The range of age of the specimens was 58 to 91 years old. To maintain pronation and supination the specimens

were fixed with a device that contained two fiberglass rods at the distal end of the ulna and radius (Pomianowski et al., 2001). Valgus and varus stress was placed on the specimens. Tests were performed with physiological loads applied to the biceps, brachialis, and triceps tendon. The elbow was also placed in different positions within the ranges of motion during the valgus and varus stress (Pomianowski et al., 2001).

In all nine specimens the valgus and varus stress laxity was greater in pronation than in supination. This study concludes that valgus and varus laxity is forearm rotation dependent (Pomianowski et al., 2001). The authors also go on to say that an increased amount of pronation used during the acceleration and deceleration phase of the throwing motion may cause more medial elbow laxity, thus increasing the risk of UCL injury (Pomianowski et al., 2001).

This study used cadavers to determine whether or not pronation and supination had an effect on elbow joint laxity. The study showed that pronation did increase joint laxity. Since this is one of the first studies to do so more research may need to be done to better understand the role of pronation in joint laxity.

Surrounding Musculature and the Role They Play in Overhead Throwing

There have been several studies examining the musculature surrounding the elbow and shoulder and its relationship with injury and the overhead throwing motion seen in baseball pitching.

Wilk, Andrews, and Arrigo (1995) looked at the abductor and adductor muscles of the shoulder and their relationship to the overhead throwing motion. The shoulder abductors are comprised of the deltoid and the supraspinatus muscle. The adductors are the latissimus dorsi, pectoralis major, teres major, coracobrachialis, and the long head of

the triceps brachii. The purpose of this study was to measure the isokinetic muscular performance in the adductors and abductors of the shoulder. This was to see the difference in the dominant and non-dominant arms of the subjects. The researchers only tested uninjured professional baseball players (Wilk, Andrews, Arrigo, 1995).

There were eighty-three baseball pitchers in the study ranging in age from 18 to 29 years. None of them had previous shoulder surgery or pain six months prior to the study. The subjects were evaluated using a Biodex Multi-Joint System. The testing was performed in the seated position for both adduction and abduction. The pitching arms were weighed to provide for gravity compensation, and each was tested at two different velocities, 180 and 300 degrees per second concentrically. Both arms were tested in the procedure and a warm-up was given. For the warm up each subject performed five sub-maximal repetitions, which was followed by three maximal contractions at the same speed. The subjects then did ten repetitions at 180 deg/sec. The same warm-up procedure was utilized with the 300 deg/sec. trial, although fifteen repetitions were performed as opposed to ten. The authors concluded that there was no significant difference in the nondominant and dominant throwing arms in shoulder abduction, but there was a difference in shoulder adduction between the nondominant and dominant arms (Wilk, Andrews, Arrigo, 1995). The shoulder adductors aid in the late cocking and acceleration phase, these muscles play a significant role in the explosive acceleration on the arm. The author concludes that the shoulder adductor muscles should be significantly stronger in the throwing athlete. (Wilk, Andrews, Arrigo, 1995).

The study was well designed and well executed. However, this study could have added one component to its testing procedures; Examining shoulders that have had

previous significant injuries to determine if the shoulder adductors and shoulder abductors had equal strength in the injured athlete. This is assuming that the shoulders have had proper rehabilitation before testing would take place.

Glousman and Baron (1992) performed a study using an electromyographic analysis to examine the musculature utilized in the overhead throwing motion. This study was done on both injured and non-injured pitchers. There were 10 pitchers that had documented UCL injuries and 30 pitchers that were non-injured. The average age of the participants was 24, and their skill levels varied from collegiate to professional (Glousman & Barron, 1992).

Electromyographic signals were recorded from eight muscles during two pitches, a fastball and curveball, for which the subjects performed the full pitching motion. The results of the study showed significant differences between the injured and non-injured pitchers. The major difference was shown during the late cocking and acceleration phase of the overhead throwing motion. All the muscles, except the biceps brachii, showed some change in muscle activity in the injured athletes (Glousman & Barron, 1992).

There was more of a difference in the pitchers throwing the fastball, but there were also significant changes in the curveball pitchers. Many of the muscles used in the throwing of these pitches differ. For instance the biceps peak activity was in the late cocking phase for the fastball in both normal and injured subjects. The curveball however showed peak biceps activity in the late cocking phase in injured elbows and during follow-through in healthy elbows. Another difference in muscle activity in both pitches was with the supinator. In the fastball it was at peak during the acceleration phase and follow-through for the injured group, whereas the healthy group experienced peak

activity during just the follow-through phase. In the curveball there was a peak activity level in injured subjects during the late cocking phase and during the acceleration phase for the healthy subjects. There was also a difference in both pitches with the brachioradialis (Glousman & Barron, 1992). This means that the muscles are in peak activity during these different phases for the injured athletes to control pain and responding to the medial laxity and increasing its activity to slow down elbow extension (Glousman & Barron, 1992).

Both injured and non-injured athletes were used in this study, although, a better balance of both would have garnered more accurate results. The researchers did, however, use the age group that showed the most injury problems, examined two different pitches, and looked more at the muscles surrounding the elbow instead of just concentrating on the shoulder, making it a more significant study than its predecessors. The study concluded that muscle activity between the injured and normal elbows occurred during the late-cocking and acceleration phase (Glousman & Barron, 1992).

Davidson and Pink (1995) conducted a study on the flexor pronator muscle group in relation to the UCL of the elbow. They used six left and five right fresh-frozen elbow cadaver specimens. The purpose of the study was to recognize the specific component of the flexor pronator musculotendinous component that lay directly over the UCL at 30, 90, and 120 degrees of elbow flexion. This would identify the specific muscles that overlie the UCL during cocking and acceleration phase of the overhead throwing motion (Davidson & Pink, 1995).

During the procedure, the elbow was dissected so the examiners could observe the UCL in relation to the musculature being tested. The observations were made at 30, 90,

and 120 degrees, each degree representing a different portion of the overhead throwing motion that was being examined. Thirty degrees represented forced full extension; 90 degrees represented the middle of the cocking and acceleration phase, and 120 degrees represented full flexion in the elbow (Davidson & Pink, 1995).

The study concluded that the flexor carpi ulnaris and the flexor digitorum superficialis muscles are located most directly over the anterior portion of the UCL during the high demand portions of the overhead throwing motion. The important findings of this study are that these muscles should be focused on for both prevention and rehabilitation of elbow injury (Davidson & Pink, 1995).

The only real limitations noted were that the researchers used cadaver specimens of non-pitching elbows instead of those from arms that had performed the overhead throwing motion as frequently as a baseball pitcher does. Using regular healthy non-pitching elbows as opposed to pitchers elbows may not conclusively show the long-term effect the overhead throwing motion may have on the ulnar collateral ligament and the surrounding flexor pronator muscles. The study may have had a different conclusion had they used the cadaver of a former baseball pitcher. However since this was an anatomical study they were not concerned with injury just range of motion.

Prevention and Rehabilitation for the Pitching Elbow

There are several ways to prevent elbow injuries in baseball. Good pitching mechanics, starting at the right age, and watching ones pitch count are just a few ways to stay healthy. However, there are instances when accidents happen which can lead to serious injury. In this era of medicine a pitcher can be brought back to health from these injuries in a shorter period of time. Since Frank Jobe performed the first ligament

replacement operation on a damaged UCL, elbow injuries don't mean retirement anymore (McNeal 2002). This particular surgery was named Tommy John surgery after the first pitcher to receive it.

Tommy John surgery is an important medical procedure. Azar, Andrews, Wilk, and Groh examined the operative treatments of UCL injuries in athletes (2000). Over a six-year period Dr. James Andrews performed 91 UCL reconstruction or repair surgeries. The patients who received the procedures ranged between the ages of 15 and 39 years. Of the 91 patients 85 were baseball players at either the professional, collegiate, high school, or recreational level. The author's purpose was to examine the results of UCL reconstruction and repair on the athletes, and make recommendations for the treatment (Azar et al., 2000).

The patients went through a four-phase rehabilitation program. Phase one began directly after surgery and continued for three weeks. During this time, the patients were put in a brace to control their elbows range of motion. The first week, the brace was set to immobilize the elbow at 90 degrees of flexion. At the beginning of the second week it was set to allow motion from 30 degrees of extension to 100 degrees of flexion. The third week allowed the elbow to go from 15 degrees of extension to 110 degrees of flexion. Every week after, five degrees was added to elbow extension and ten degrees to elbow flexion. The first phase of rehab worked with hand and wrist range of motion and hand grasping exercises. In addition, isometric strengthening was performed on the shoulder and arm musculature. Phase two spanned weeks 4 through 8, and consisted of progressive isotonic resistive exercises, and by this time, full range of motion in the rotator cuff was

restored. At the end of week eight, the immobilizing brace was removed, thus concluding the second phase of rehab (Azar et al., 2000).

Phase three was considered weeks 9 through 13. This phase implemented an advanced strength-training program, and put emphasis on restoring full range of motion to the elbow, shoulder, and wrist joints. Isotonic exercises were increased and more attention was focused on the scapular muscles, elbow flexors and extensors, and the supinators and pronators. During week 12, the athletes were introduced to plyometrics (Azar et al., 2000).

Phase four was recommended to last from week 14 to week 26. For baseball pitchers an interval-throwing program was initiated. The athletes started throwing at a short distance and gradually the distance increased if their elbow was completely pain free. Once the throwing program was complete, they returned to a competitive level of play. If pain persisted for an extended period of time, the pitchers were instructed to decrease their throwing distance (Azar et al., 2000).

After the entire rehabilitation was completed, the subjects were asked to do a follow up. Of the original 91 participants, 24 were not available for follow up. Eighty one percent of those with reconstruction had a successful outcome, and 63 percent with repairs returned to competitive play. The authors concluded that reconstructions appeared to be more successful than UCL repairs (Azar et al., 2000).

This study looked at the surgical procedure and its effectiveness. The results were validated in part by using a large group of subjects. The study, however, did mention that a long-term study might benefit Tommy John surgery. Perhaps the only thing the study

did not look at was the use of rehabilitation in the follow up portion and if the subjects felt the rehabilitation was really beneficial.

Andrews and Timmerman (1995) performed a study looking at the rehabilitation involved with the surgical procedure of the elbow rather than just the surgical procedure involved in UCL reconstruction. This study was completed over the course of five years and involved 72 baseball players who underwent arthroscopic or open elbow surgery. The mean age of the participants was 24 years; there were 17 left-handed and 55 right-handed players. Of the 72, 64 were pitchers (Andrews & Timmerman, 1995).

The players that underwent reconstruction went through the same four-phase rehab schedule as the study by Azar et al. (2000). The athletes that underwent arthroscopic surgery returned to throwing after 6 to 8 weeks. Of the 72 players, 13 were unavailable for a follow-up. Forty-seven of the remaining 59 returned to play at least one season of baseball. Ten patients did not return due to the surgery, and two did not return for other reasons (Andrews & Timmerman, 1995).

The authors concluded that there was a 73 percent success rate for professional baseball players to return to competitive play who have received elbow surgery (Andrews & Timmerman, 1995). This study looked at only professional athletes so the results for people with a lower ability level may vary. The only limitation in this type of study is the difficulty of getting patient follow-up.

Summary

The ulnar collateral ligament of the elbow is a vital part of the throwing elbow. It helps stabilize the elbow during the overhead throwing motion. It is during this motion

however, that the ligament can suffer the most damage. When athletes start putting a heavy strain over that area at a young age they are risking serious injury.

When a child learns to pitch they should be aware of such things as proper pitching technique, pitch count, and should learn when to learn to throw specific pitches. The world of baseball has seen plenty of athletes suffer UCL related injuries, all of which could have been prevented had they started their careers the right way.

Keeping a healthy elbow means keeping the whole area strong and resting it when needed. The surrounding musculature plays an important role in keeping the area healthy. The elbows supinators, pronators, flexors, and extensors should all be kept healthy. When pain is reported it should be addressed immediately.

Tommy John surgery has helped restore a great number of baseball pitchers elbows, but injuries are still going to occur. With proper off season conditioning, good biomechanics, and patience, UCL reconstructions can be kept out of baseball.

CHAPTER III

METHOD

The present investigation compared the throwing history and physical characteristics of collegiate baseball pitchers with current elbow health. The purpose of the study was to determine whether or not pitch type, pitch count, and pitching outings per week along with height, weight, stride length, limb length, joint laxity, and elbow flexion and extension could predict the likelihood of future elbow injuries.

Subjects

The subjects for this study ranged in age from 18 to 25 years. Pitchers from a current NCAA division I baseball team and a NJCAA division I baseball team were recruited to participate in the study. At the time of the data collection all of the subjects were in the middle of the collegiate baseball competitive season. The NCAA division I baseball pitchers were from Eastern Illinois University and the NJCAA division I baseball players were attending Lakeland College. They were chosen because of the skill level at which they were competing. The subjects were baseball players that were current starting, middle-relief or closing pitchers. The subjects were assigned to one of three groups based upon whether or not they were currently injured, experiencing elbow pain, or had healthy elbows.

Instrumentation

Subjects completed a survey inquiring about their past and present baseball experiences (Appendix A). Participants answered questions about how long they had been pitching, the types of pitches they have thrown, how long they have been throwing those pitches, what their pitch count had been at four different skill levels, and questions

concerning their past and present elbow health. The subjects also were asked questions about any surgical procedures performed on their throwing elbow. Included in the survey was the McGill pain scale. This scale instructed the subjects to rate their present pain on a scale of zero to ten, zero being no pain and ten being the worst pain possible. The scale also has a portion where the subjects circle words that describe their pain.

Procedures

Subjects completed the survey before a practice session in the middle of the collegiate season. The participants were given instruction and informed as to what was the purpose of the survey. After the subjects finished the survey the physical measurements were made.

The subject's height and weight was obtained from measurements taken by a certified athletic training at the beginning of the season. Height was measured in centimeters and weight was measured in kilograms. Stride length was measured by having the subjects perform a complete pitching stride similar to that of a game situation. The subjects were instructed to stand on the pitchers mound and go through the motion of pitching. Stride length was measured from the front of the pitching rubber to the heel of foot of the stride leg. The measurement was taken one time.

Limb length was measured on the dominant arm of the subject using a fiberglass tape measure (Creative Health Products). Measurements for the upper arm started at the acromion process and extended distally to the olecranon process of the ulna. Measurements for the lower limb were made from the olecranon process of the ulna and extended down to the styloid process of the radius. All anthropometric measurements were recorded in centimeters.

Joint laxity was measured using the valgus stress test. This was done by a certified athletic trainer and the author. The evaluator held the subject's wrist and extended the arm. The other hand was placed over the lateral epicondyle of the humerus. The evaluator applied stress to the lateral epicondyle. A positive test was indicated by the observation of a gapping in the UCL (Arnheim and Prentice, 2000). Laxity was graded on a scale of zero to plus three, zero being no laxity and plus three being the most extreme end of laxity. Elbow flexion and extension were measured using a goniometer. A certified athletic trainer and the author performed this measurement. The subjects were instructed to fully extend their arm and the extension reading was taken. The goniometer was aligned with the styloid process of the radius and the acromion process and it was placed over the lateral epicondyle. The subject fully flexed their arm while the degrees of flexion were measured.

Data Analysis

Descriptive statistics (mean and standard deviation) were calculated for the dependant variables by group. Differences among the groups for dependent variables were assessed using ANOVA (SPSS version 11.5) was used to calculate statistics. An alpha level of less than 0.05 was used to indicate statistical significance in this study.

CHAPTER IV

RESULTS/DISCUSSION

The purpose of this study was to determine which factors are most related to serious elbow trauma in collegiate pitchers. It was hypothesized that a pitcher's playing behavior in regard to pitch count, pitch type, and weekly pitching frequency would directly have a positive impact on elbow injuries. Also such factors as height, weight, stride length, elbow joint laxity, upper and lower arm length, and flexion and extension of the elbow were examined to determine if they contribute to the risk of injury.

Results

Subjects

Twenty six collegiate baseball players were given a survey to seek information on their past pitching habits and current elbow health. All twenty-six of the surveys were completed and received for analysis.

The group of twenty-six male collegiate baseball players had been pitching for a mean of 10.27 ± 3.49 years. Of the twenty-six subjects eleven indicated they were a starting pitcher. Six of the subjects indicated that they were utilized as a starting pitcher and either a long relief, middle relief, or closing pitcher. Six subjects were long or middle relief or closing pitcher. These pitching roles require fewer innings and lower pitch counts, but they may pitch in more games during the week. Three subjects indicated they were utilized as a closer only.

Groups

Responses to the questions related to pain and injury separated the subjects into three groups. Group 1 consisted of subjects that indicated they had both pain and a history of injury in their throwing elbow (n=8). Group 2 consisted of nine participants who indicated they had pain before, during, and/or after pitching but did not have a documented injury. Group 3 were subjects who indicated they had no pain before, during, or after pitching, and did not have a current, or history of injury.

Three of the subjects in group 1 were injured at the time of the study. Of the three presently injured subjects one had a possible UCL tear and a pronator teres strain, one had a possible cartilage tear, and one had a muscle strain, and possible UCL damage. Two those three subjects had not been pitching, so they did not report pain before, during, or after throwing.

The other five subjects had a previous injury. Of the previously injured subjects one had a pinched ulnar nerve, and four had elbow tendonitis. The five subjects who had previous injury were still reporting pain.

Group 1 and group 2 are the two groups that indicated they had pain before, during or after pitching or they were injured. Six of the eight subjects in group 1 reported having pain before, during or after pitching while the other two subjects were injured and not throwing during the time of the study. Three of the six active pitchers indicated they had pain before pitching with a mean pain level of six on a scale of zero to ten. Four had pain during pitching with a mean pain level of 6.25 out of ten, and six had pain after pitching with a mean score of 6.50 out of ten. Two subjects had pain only after

pitching, while one subject had pain during, and after pitching, and three subjects had pain before, during, and after pitching. Subjects were asked to describe their pain using a list of words. However, there was no pattern observed in the words they circled among the groups.

Nine subjects in group 2 had pain before, during, or after throwing. Three subjects noted having pain before they pitched with a mean pain score of 2.67 out of ten. Two subjects said they had pain while pitching, one rated the pain as a two, and the other subject gave a rating of four out of ten. Eight subjects said they had pain after throwing with a mean pain score of 3.75 out of ten. Five subjects had pain just after pitching with a mean score of 3.4 out of ten, one had pain before, during, and after with a score of 3.33 out of ten, one subject had pain during and after with a score of two out of ten, one subject had pain before with a mean score of three out of ten, and one subject had pain before and after throwing with a mean score of five out of ten.

Pitching History

Years pitched and pitch type

The subjects in group 1 had been pitching for a mean of 10.13 years \pm 4.26. Three subjects said they were starting pitchers, while one labeled himself as a starting pitcher, middle relief pitcher, and a long relief pitcher. One subject labeled himself as a starting pitcher and a long relief pitcher. One subject was a middle relief pitcher and long relief pitcher, and two were closing pitchers.

Table 1 Age at Which Pitch Type was Learned Group 1 (N=8)

Pitch Type	n	Mean Age Learned (years)	\pm SD
Fastball	8	8.88	2.90
Curveball	8	13.13	2.90
Slider	5	15.80	2.05
Change-up	7	13.86	4.26
Knuckleball	0	-	-
Split-finger	1	19.00	-
Sinker	1	18.00	-

Table 2 Age at Which Pitch Type was Regularly used Group 1 (N=8)

Pitch Type	n	Mean Age Learned (years)	\pm SD
Fastball	8	10.00	4.63
Curveball	8	13.50	2.51
Slider	5	16.00	2.12
Change-up	7	14.57	3.41
Knuckleball	0	-	-
Split-finger	1	19.00	-
Sinker	1	18.00	-

The types of pitches thrown by subjects in group 1, when those pitches were learned and when they were used regularly are shown in Table 1 and Table 2 respectively. The split-finger fastball and sinker were learned in college, while all other pitches were learned prior to entering college.

Group two consisted of nine subjects. This group had been pitching for a mean of $10.56 \text{ years} \pm 3.28$. Five subjects were starting pitchers, two were middle relief, one was both a starter and closer, and one was both a starter and a middle relief pitcher.

Tables 3 and 4 illustrate the pitch type, with mean and standard deviation when the pitch was learned and when the subjects began to use the pitch on a regular basis. For group two nobody threw a knuckleball, and only one threw a split-finger fastball and sinker.

Group three consisted of nine subjects, who had been pitching for mean of $10.11 \text{ years} \pm 3.37$. Three were starting pitchers, one was middle relief, one was a closer, one was a starting pitching, middle relief, and long relief, one was a middle and long relief, was a middle, long, and closer, and one subject was a starting pitcher and closer. Pitch type for this group and age at which each was learned and used regularly are shown in Tables 5 and 6 respectively.

Pitch Count

The subjects were asked whether or not they had a pitch count in all the leagues in which they pitched. The leagues included little league (ages 8 to 11 years), Jr. High school (ages 12 to 14 years), high school (ages 15 to 18 years), and college (ages 18 to 24 years). Pitch counts at each of the four skill levels for the three groups is shown in table 7 (group one), Table 8 (group two), and Table 9 (group three). The number of games

Table 3 Age at Which Pitch Type was Learned Group 2 (N=9)

Pitch Type	n	Mean Age Learned (years)	±SD
Fastball	9	7.89	1.36
Curveball	9	13.22	1.48
Slider	5	14.40	1.52
Change-up	8	12.75	3.54
Knuckleball	0	-	-
Split-finger	2	12.50	-
Sinker	1	14.00	-

Table 4 Age at Which Pitch Type was Regularly used Group 2 (N=9)

Pitch Type	n	Mean Age Learned (years)	±SD
Fastball	9	8.22	1.63
Curveball	9	14.00	1.23
Slider	5	15.00	0.71
Change-up	8	13.50	3.51
Knuckleball	0	-	-
Split-finger	1	15.00	-
Sinker	1	16.00	-

Table 5 Age at Which Pitch Type was Learned Group 3 (N=9)

Pitch Type	n	Mean Age Learned (years)	\pm SD
Fastball	9	8.00	2.55
Curveball	9	13.56	1.74
Slider	5	15.60	2.70
Change-up	7	15.43	4.16
Knuckleball	0	-	-
Split-finger	3	15.67	-
Sinker	1	18.00	-

Table 6 When Pitch Type was Regularly used Group 3 (N=9)

Pitch Type	n	Mean Age Learned (years)	±SD
Fastball	9	8.78	2.95
Curveball	8	14.38	1.85
Slider	5	16.60	2.97
Change-up	7	15.43	4.17
Knuckleball	0	-	-
Split-finger	3	16.67	1.53
Sinker	0	-	-

Table 7 Pitch Counts for Each Skill Level Group 1 (N=8)

Skill Level	Number of Subjects*	Pitch Counts per Game			
		20-40	41-60	61-80	80 +
Little League	2	0	2	0	0
Junior High	5	0	0	3	2
High School	7	0	0	0	7
College	8	2	0	0	6

* not all subjects competed in little league, junior high, and high school

Table 8 Pitch Counts For Each Skill Level Group 2 (N=9)

Skill Level	Number of Subjects*	Pitch Counts per Game			
		20-40	41-60	61-80	80 +
Little League	2	0	2	0	0
Junior High	3	0	0	3	0
High School	8	0	0	1	7
College	9	0	2	0	7

* not all subjects competed in little league, junior high, and high school

Table 9 Pitch Counts For Each Skill Level Group 3 (N=9)

Skill Level	Number of Subjects*	Pitch Counts per Game			
		20-40	41-60	61-80	80 +
Little League	1	0	0	1	0
Junior High	1	0	0	0	1
High School	7	0	0	0	7
College	8	0	0	2	6

* not all subjects competed in little league, junior high, and high school

pitched per week is shown in Tables 10, 11, and 12. Not all subjects competed in the first three skill levels.

ANOVA revealed no significant differences between the groups in age at which the subjects learned the pitch (Figure 4) and age at which they started regularly throwing the pitch (Figure 5). Figure 6 illustrates the differences among the three groups concerning years pitched. ANOVA showed no significant difference in years pitched among the three groups.

Physical Attributes

Tables 13 through 15 show mean and standard deviation for each group in stride length, height, and weight for each group. Figure 7 illustrates flexion, and figure 8 illustrates upper, lower, and total limb length between the groups. ANOVA showed no significant differences among the three groups in stride length, height, weight, extension, lower limb length, and total limb length. Extension in group1 was a mean of $-.75 \pm 5.73$, group 2 was $.11 \pm 4.14$, and group 3 was $.00 \pm 2.18$

There was a significant difference between groups 1 and 2 for elbow flexion ($p = .046$) and upper arm length ($p=.022$). There was however, no significant differences between either of these groups and group three.

Joint laxity was also measured during this portion of the study. A total of six subjects had a joint laxity of +1, while one had a joint laxity of +2. Group one had one subject with a +1 and one with a +2. Three subjects in group 2 had a +1, and two had a +1 in group three. Other than one subject with a +2 laxity in group 1 no real differences were observed in this variable among the groups.

Table 10 Games Pitched per Week for Each Skill Level Group 1 (N=8)

Skill level	1 game	Games pitched per week*		
		2 games	3 games	4+games
Little league	3	3	1	0
Jr. High	2	5	0	0
High School	1	5	1	0
College	4	1	2	1

* not all subjects competed in little league, junior high, and high school

Table 11 Games Pitched per Week for Each Skill Level Group 2 (N=9)

Skill level	Games pitched per week*			
	1 game	2 games	3 games	4+games
Little league	1	2	5	0
Jr. High	1	6	1	1
High School	2	2	4	1
College	5	3	0	1

* not all subjects competed in little league, junior high, and high school

Table 12 Games Pitched per Week for Each Skill Level Group 3 (N=9)

Skill level	1 game	Games pitched per week*		
		2 games	3 games	4+games
Little league	3	6	0	0
Jr. High	1	8	0	0
High School	2	4	3	0
College	5	4	0	0

* not all subjects competed in little league, junior high, and high school

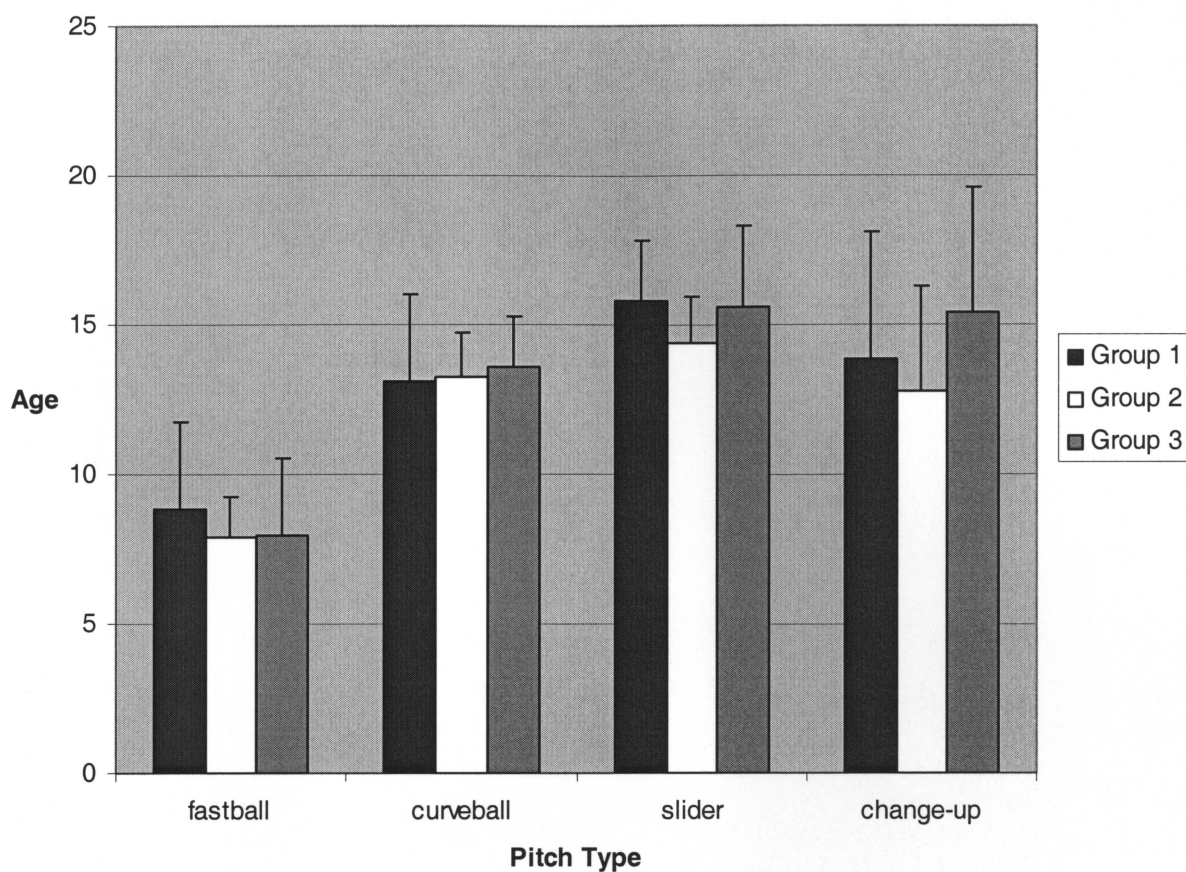
Figure 4 Age at Which Pitch Type was Learned in All Groups

Figure 5 Age at Which Pitch Type was Regularly used by Group

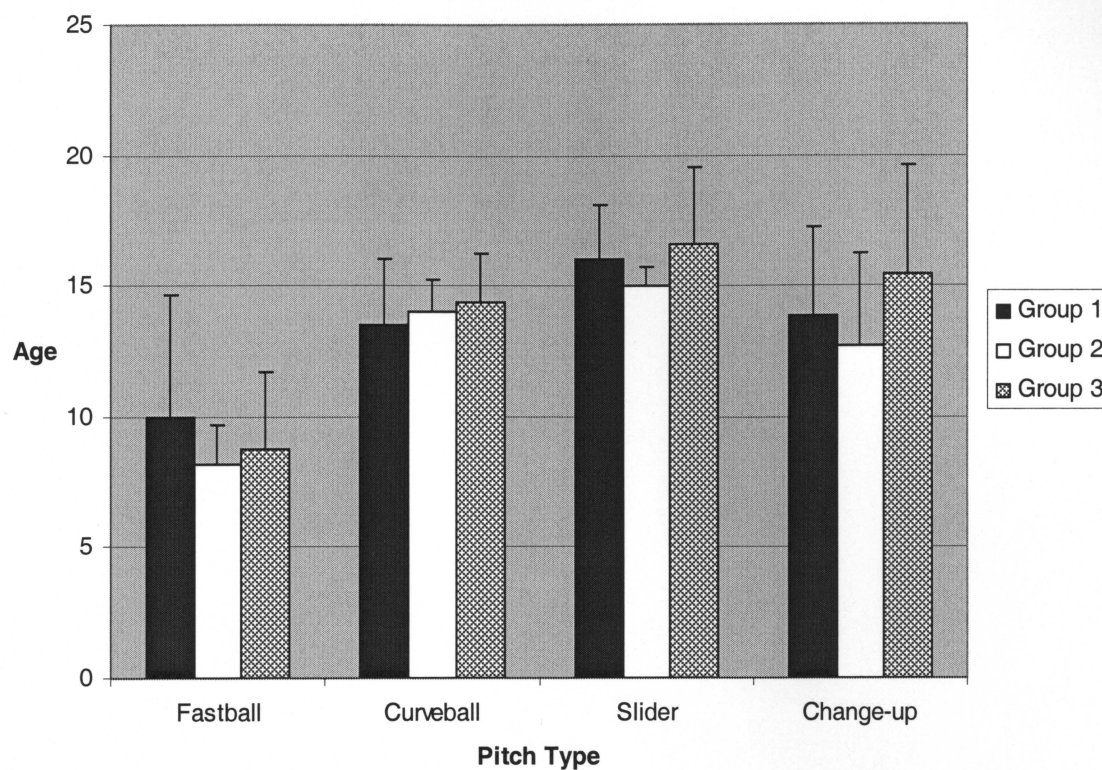


Figure 6 Number of Years Pitched for Each Group

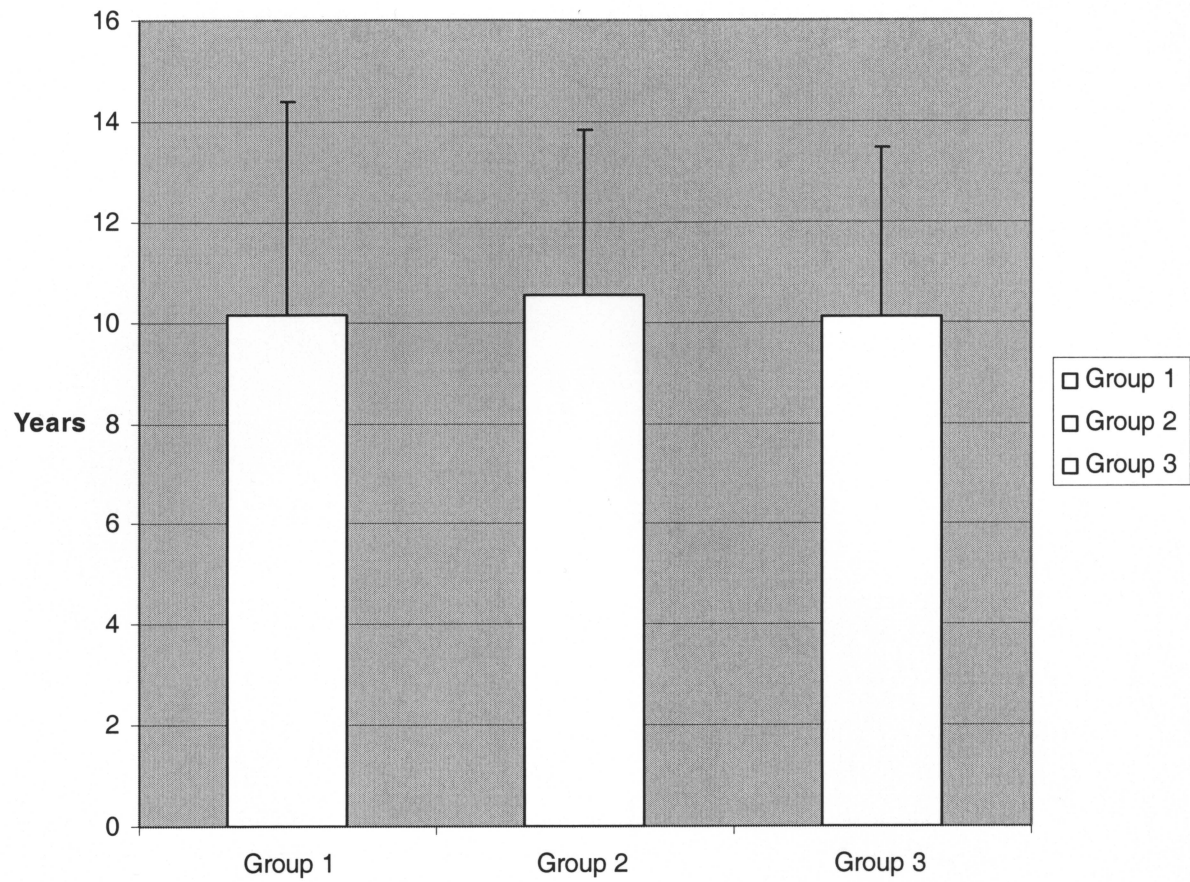


Table 13 Descriptive Statistics for Stride Length by Group, Group 1 (n=8), Group 2 (n=9), and Group 3 (n=9)

Group number	Mean Stride Length (cm)	\pm SD
Group One	121.62	16.92
Group Two	126.72	11.10
Group Three	125.88	10.19

Table 14 Descriptive Statistics for Height by Group Group 1 (n=8), Group 2 (n=9), and Group 3 (n=9)

Group Number	Height Mean (cm)	\pm SD
Group One	187.01	5.91
Group Two	183.16	8.66
Group Three	186.55	6.61

Table 15 Descriptive Statistics for Weight by Group Group 1 (n=8), Group 2 (n=9), and Group 3 (n=9)

Group Number	Weight Mean (kg)	\pm SD
Group One	83.80	5.90
Group Two	80.14	11.56
Group Three	87.44	6.61

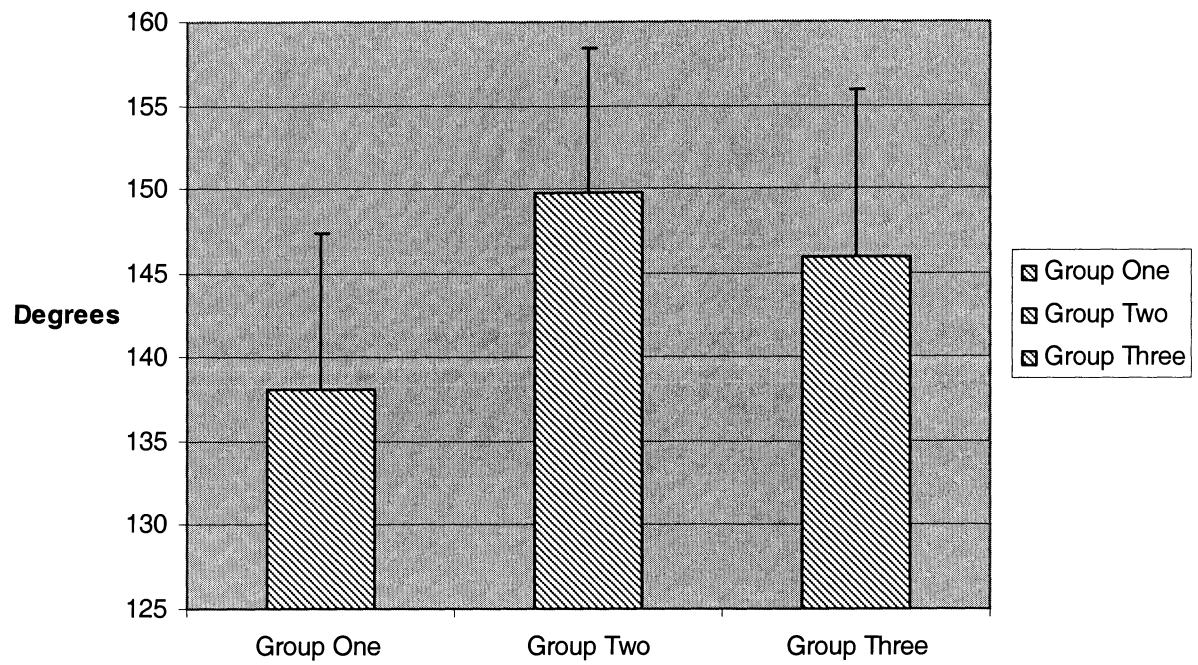
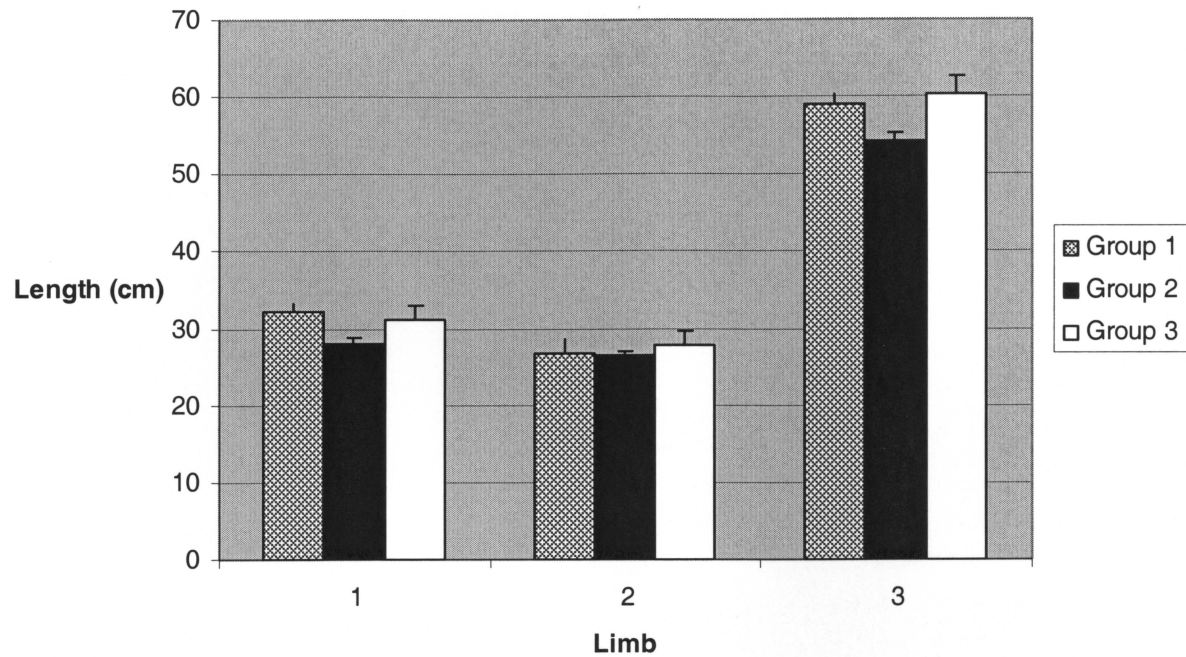
Figure 7 Elbow Flexion by Group

Figure 8 Arm Lengths by Group



Discussion

Pitchers put a considerable amount of strain on their throwing elbow. Many of their injuries are due to the accumulation of micro traumas. Factors that might attribute to elbow injuries were examined in the present study was pitch type, pitch count, pitching frequency per week, and physical measurements. The subjects in the present study had been pitching for a mean of 10.27 years and were competing at the collegiate level. The subjects had a mean height and weight of 73.04 inches and 83.97 kg. A study by Wilk et al.(1995) showed his collegiate subjects had a mean weight of 90.45 kg and a mean height of 73 inches. (Wilk et al. 1995). The subjects in the present study had been pitching for a mean of 10.27 ± 3.49 years. In a similar study of college pitchers, Saskaki et al. had subjects that had been pitching for a mean of 10.5 years. Several studies have found pitch type to be an important factor in predicting the development of elbow injuries. Lyman et al (2002), found the curveball was associated with a 52 percent increase in pain in little league pitchers shoulders and elbows. The curveball has been shown to put increasing stress on the elbow joint (Cain et al., 2001). This is because the curveball requires a skill of mastering a new set of mechanics. Therefore, it not only takes a child longer to learn how to throw a curveball, the actual mechanics of the pitch differ from that of a fastball or change-up (Cain et al., 2001). Also throwing a curveball produces a more forceful supination and ulnar deviation movement which places more stress on the elbow (Whiteside et al. 1999). Although groups 1 and 2 did throw the curveball at an earlier age than group 3, the difference was non-significant. The change-up was another pitch that was thrown earlier by groups one and two, but showed no

significance in predicting injury. However the change-up has been widely reported as a safe pitch (Lyman et al., 2002).

Years pitched, pitch count, and games pitched per week were similar amongst the three subject groups. Lyman et al (2002) found high pitch counts to be a contributing factor to increased elbow injuries. High pitch counts at any level can increase the risk of overuse injury (Lyman et al., 2002). Congeni (1994) showed that a pitch count higher than 100 pitches per game is considered a high pitch count (Congeni, 1994). In the present study there were no significant differences among the groups in pitch count. No subject had a high pitch count in the early skill levels of pitching. There were, however, differences among the groups in the number of games pitched per week. Groups one and two had more subjects pitching 3 games a week than subjects in group three. Group two had five subjects pitch three games a week in little league and four pitch three games a week in high school. Whereas group three had no subjects pitch three games a week in little league, and three subjects pitch three games a week in high school. Stress placed on an athlete at an early age can lead to overuse injuries (Whiteside et al. 1999). The current study indicates that the subjects in groups one and two, although they had similar pitch counts per game with that of group 3, did throw more total pitches per week at a younger age. This is significant in that it raises the total number of pitches thrown per week. This should caution little league coaches to use a given pitcher less often. So even if they have set pitch count per pitching outing, if they are pitching three to four times a week as opposed to one time a week they are putting more stress on their elbow. Lyman et al. (2001) conducted a study and found that subjects that were accumulating a higher pitch

count had an increased risk of pain and injury. The author went on to say that a pitch count over 75 can increase the risk of elbow injury.

The present study showed that there were no significant differences among the groups in stride length, height, weight, elbow extension, lower limb length, and total limb length. There were differences between groups 1 and 2 concerning elbow flexion, but no difference between 1 and 3 or 2 and 3. Group 1 showed less flexion than the second group. This may be because their injuries have caused less range of motion in there pitching elbows or a combination of pitching frequency and a “tighter” elbow.

Ellenbecker et al. (1998) reports that lack of flexibility can decrease active muscular protection of the medial elbow thus putting greater stress on the UCL (Ellenbecker et al., 1998). Fleisig et al (1995) also examined flexibility and concluded that insufficient flexibility may forbid proper throwing mechanics (Fleisig et al., 1995) Arm length was also a significantly different between groups 1 and 2. Fleisig et al. (1995) also examined limb length, but found no relationship with elbow injuries and no norms were given for the subjects. No other studies were found that examined upper limb length and baseball pitchers. McLean and Parker (1989) examined lower limb length in Australian cyclist but no significant correlation existed between limb length and injury (McLean & Parker, 1989). Stride was assessed in the present study as well, with the subjects having a mean of 124.84 ± 11.8 cm. Fleisig (1996) reported that stride length should be $87 \pm 5\%$ of body height when measured from the pitching rubber to the lead ankle (Fleisig, 1996). The present study was 67 ± 1.65 . A study by Elliot, Gibson, and Thurston, measured stride and reported a mean stride length of 154.2 ± 8.8 cm in their subjects.

CHAPTER V

SUMMARY AND CONCLUSION

The pitching elbow is very important to a pitchers arm. Keeping the pitching elbow healthy can ensure a long and successful pitching career. The purpose of this study was to determine which factors are most related to elbow trauma in collegiate pitchers. It was hypothesized that a pitchers playing behavior in regard to pitch count, pitch type, and pitching frequency would relate to presence of pain and injury. It was further hypothesized that physical factors such as height, weight, stride length, elbow joint laxity, upper and lower arm length, and flexion and extension of the elbow were examined to determine if they contribute to the increased risk of injury. Twenty-six collegiate baseball pitchers were surveyed about their pitching past. Questions involving their pitch type, pitch count, pitching appearances per week, if they had pain before, during, or after pitching, and whether or not they have suffered any type of elbow injury due to pitching were presented in the survey. Physical measurements of stride length, elbow flexion and extension, joint laxity, height, weight, and arm length were completed. After the surveys and measurements were collected, the subjects were placed into one of three groups; injured (group one), pain (group two), no injury/no pain (group three). Descriptive statistics were calculated for each group. Differences among the groups for dependent variables were assessed using ANOVA. An alpha level of less than 0.05 was selected to indicate statistical significance in this study. Significant differences were found between groups one and two concerning elbow flexion ($p = .046$) and upper arm length ($p=.022$).

There were also differences between groups one and two and group three in pitching frequency.

Conclusion

Based upon the data collected and results of this study the following conclusions were drawn:

- There was no evidence that pitch type or a high pitch count was associated with elbow injury.
- Pitching frequency per week at the little league and high school levels were higher in groups that experienced pain and injury than in the group that does not experience pain or injury
- There was less range of motion in elbow flexion in the group that had injury than in the group with pain only.
- Upper arm length showed a difference between groups 1 and 2 with group 1 having a longer upper limb.
- No other physical attributes were associated with risk of injury in the elbow.

It was concluded from the results that a high pitching volume (frequency * pitch count) at a young age, limited range of motion in elbow flexion, and a longer upper limb length may contribute to a higher risk of elbow injury by the time pitchers reached the collegiate level.

Recommendations for Further Studies

Several recommendations can be made from the present study. The groups should contain a larger number of subjects; especially the injury group. A survey should have taken place before and after the collegiate season. The pain group should have a short follow up during the baseball season to inquire about their present elbow pain. Studying a variety of younger age groups to examine whether or not coaches and parents are implementing such things as pitch type and keeping a pitch count would help determine risk of injury. In the present investigation the injury group had a wide variety of injuries, future studies may benefit by using a group with all subjects having the same injury. The subjects should also come from different area of the country. The stride length should have been measured more than once for each of the subjects.

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APPENDIX A

Name (Optional):

Age:

PART I.

How long have you been a pitcher _____

1. Are you a (circle all that apply):
 1. Starting pitcher
 2. Middle relief pitcher
 3. Long relief pitcher
 4. Closer

2. Which of the following pitches do you throw (circle all that apply):
 1. Fastball (2 or 4 seam)
 2. Curveball
 3. Slider
 4. Knuckleball
 5. Split finger fastball
 6. Sinker
 7. Change-up
 8. Other _____

3. At which age did you learn to throw the following pitches:
 1. Fastball (2 or 4 seam) _____ years old
 2. Curveball _____ years old
 3. Slider _____ years old
 4. Knuckleball _____ years old
 5. Split finger fastball _____ years old
 6. Sinker _____ years old
 7. Change-up _____ years old
 8. Other _____, _____ years old

4. At which age did you start to use the following pitches on a regular basis;
 1. Fastball (2 or 4 seam) _____ years old
 2. Curveball _____ years old
 3. Slider _____ years old
 4. Knuckleball _____ years old
 5. Split finger fastball _____ years old
 6. Sinker _____ years old
 7. Change-up _____ years old
 8. Other _____, _____ years old

5. Did you ever have a pitch count (record number of pitches thrown in a pitching appearance) when you played in: (circle all that apply)

- | | | |
|---------------------------------|-----|----|
| 1. Little League (ages 8 to 11) | YES | NO |
| 2. Junior High (ages 12 to 14) | YES | NO |
| 3. High School (ages 15 to 18) | YES | NO |
| 4. College (ages 18 to 23) | YES | NO |

6. If you had a pitch count (record number of pitches thrown in a pitching appearance) what was it: (circle number to the right)

- | | | | | |
|---------------------------------|----------|----------|----------|-----|
| 1. Little League (ages 8 to 11) | 20 to 40 | 41 to 60 | 61 to 80 | 81+ |
| 2. Junior High (ages 12 to 14) | 20 to 40 | 41 to 60 | 61 to 80 | 81+ |
| 3. High School (ages 15 to 18) | 20 to 40 | 41 to 60 | 61 to 80 | 81+ |
| 4. College (ages 18 to 23) | 20 to 40 | 41 to 60 | 61 to 80 | 81+ |

7. How many times a week did you pitch in a competitive game situation in the following leagues: (circle number to the right)

- | | | | | |
|------------------|--------|---------|---------|----------|
| 1. Little League | 1 game | 2 games | 3 games | 4+ games |
| 2. Junior High | 1 game | 2 games | 3 games | 4+ games |
| 3. High School | 1 game | 2 games | 3 games | 4+ games |
| 4. College | 1 game | 2 games | 3 games | 4+ games |

PART II

8. Do you experience pain in your elbow before throwing? YES NO

If YES, on a scale of 0 to 10, 0 being no pain and 10 being intolerable pain, how would you rate the pain you feel

0 1 2 3 4 5 6 7 8 9 10

9. Do you experience pain in your elbow while throwing? YES NO

If YES, on a scale of 0 to 10, 0 being no pain and 10 being intolerable pain, how would you rate the pain you feel

0 1 2 3 4 5 6 7 8 9 10

10. Do you experience pain in your elbow after throwing? YES NO

If YES, on a scale of 0 to 10, 0 being no pain and 10 being intolerable pain, how would you rate the pain you feel

0 1 2 3 4 5 6 7 8 9 10

11. If you answered YES to question 8,9, or 10 answer the next question:

What does your pain feel like?

Some of the words below describe your present pain. Circle only the words that best describe it.

- | | | | | | |
|---------------|-------------|------------|-----------|----------|----------|
| 1. Flickering | Quivering | Pulsing | Throbbing | Beating | Pounding |
| 2. Jumping | Flashing | Shooting | | | |
| 3. Pricking | Boring | Drilling | Stabbing | | |
| 4. Sharp | Cutting | Lacerating | | | |
| 5. Pinching | Pressing | Gnawing | Cramping | Crushing | |
| 6. Tugging | Pulling | Wrenching | | | |
| 7. Hot | Burning | Scalding | Searing | | |
| 8. Tingling | Itchy | Smarting | Stinging | | |
| 9. Dull | Sore | Hurting | Aching | Heavy | |
| 10. Tender | Taut | Rasping | Splitting | | |
| 11. Tiring | Exhausting | | | | |
| 12. Sickening | Suffocating | | | | |
| 13. Fearful | Frightful | Terrifying | | | |

14. Punishing	Grueling	Cruel	Vicious	Killing
15. Wretched	Blinding			
16. Annoying	Troublesome	Miserable	Intense	Unbearable
17. Spreading	Radiating	Penetrating	Piercing	
18. Tight	Numb	Drawing	Squeezing	Tearing
19. Cool	Cold	Freezing		
20. Nagging	Nauseating	Agonizing	Dreadful	Torturing

12. Have you ever had any documented medical problems with your throwing elbow?

YES

NO

If YES, what:

13. Have you ever had surgery on your elbow?

YES

NO

If YES what:

PART III

To be filled in by evaluator

1. Stride Length _____
2. Elbow Flexion _____
3. Elbow Extension _____
4. Joint Laxity _____
5. Height _____
6. Weight _____
7. Segment Length
 - a. Upper Arm _____
 - b. Lower Arm _____
 - c. Total Arm _____